

## Variety, seeding rate and disease control affect faba bean yield components

I. Plūduma-Pauniņa<sup>1,2,\*</sup>, Z. Gaile<sup>1</sup>, B. Bankina<sup>1</sup> and R. Balodis<sup>1</sup>

<sup>1</sup>Latvia University of Life Sciences and Technologies, Faculty of Agriculture, Institute of Soil and Plant Science, Liela street 2, LV-3001 Jelgava, Latvia

<sup>2</sup>Latvia University of Agriculture, Faculty of Agriculture, Research and Study Farm “Pēterlauki”, Platone parish, LV-3021, Latvia

\*Correspondence: [ievapluuduma@inbox.lv](mailto:ievapluuduma@inbox.lv)

**Abstract.** Faba beans (*Vicia faba* L.) have been grown since 8000 years B.C. in the Middle East. Despite their long growing history in the world, there are only few researches carried out in Baltic region in last decades about variety, seeding rate and disease control effect on faba beans' growth, development and yield formation. Research was carried out at the Latvia University of Life Sciences and Technologies during 2015–2017. Three factors were researched: A – variety ('Laura', 'Boxer', 'Isabell'), B – seeding rate (30, 40 and 50 germinate able seeds m<sup>-2</sup>), C – treatment with fungicide (with and without application of fungicide Signum (1 kg ha<sup>-1</sup>)). Meteorological conditions were diverse and sometimes caused stress for crop, but in general they favoured faba beans' growth and development. High average yield of the field beans was obtained during all three trial years, however, yield differed significantly among them. Sowing time was constantly quite early, germination took longer time as expected due to the low air temperature, but later, temperature and humidity level improved and conditions were suitable for plant growth and development with some exceptions during flowering and pod filling. Number of productive stems per 1 m<sup>2</sup> was significantly affected only by seeding rate. Plant height in trial site was affected by variety ( $p < 0.001$ ), fungicide application ( $p = 0.008$ ) and meteorological conditions ( $p < 0.001$ ) of the year. Number of pods per plant differed depending on trial year ( $p < 0.001$ ). Number of seeds per plant had a close positive correlation with number of pods per plant. Whereas number of seeds per pod was a relatively stable and typical characteristic for variety. We can observe correlation between faba bean yield and number of productive stems per 1 m<sup>2</sup> at harvest, plant height, number of pods and seeds per plant.

**Key words:** field beans, agrotechnology, phenology, yield components.

## INTRODUCTION

Faba beans (*Vicia faba* L.) is the third most important legume plant in the world after soy beans (*Glycine max* L.) and peas (*Pisum sativum* L.) (Singh et al., 2013). In Latvia, faba beans, known also as field, broad and horse beans, have been grown for ages, but nowadays, commercially mainly *Vicia faba* var. *minor* is grown for animal feed mostly.

Faba beans are known for their high value for green forage, they improve soil fertility and leave good effect on after-crops (Sahile et al., 2008).

During last 10 years, faba bean sowing area has grown more than 50 times in Latvia, reaching 42.3 thousand ha in 2017, which is about 3.3% from all agricultural land in the country. Despite important agronomical impact of faba beans, farmers' growing interest about this crop can be mostly explained by European Union greening requirements.

The last major study about several aspects of faba beans' growing in Latvia was performed in 1960-ties (Holms, 1967). Since then, there have not been plenty of studies about faba bean in Baltic countries or even in Northern Europe. Several various studies about variety and seeding rate impact on faba bean yield can be found (Skjelvag, 1981; Lopez-Bellido et al., 2005; Patrick & Stoddard, 2010; Flores et al., 2013), some studies about severity of diseases (Villegas-Fernandez et al., 2009; Bankina et al., 2016), but additional studies are necessary. Our research about faba beans is the first so extensive study of last decades in Latvia. The aim of this paper was to estimate how variety, seeding rate and disease control in different years affect development and yield components of faba bean.

## MATERIALS AND METHODS

Research was carried out from 2015 until 2017, at Latvia University of Life Sciences and Technologies Research and Study farm "Pēterlauki" (56°32'31.2"N 23°42'57.6"E). Researched factors all three years were: variety (three different faba bean varieties – 'Laura', 'Boxer', 'Isabell'), seeding rate (three different seeding rates – 30, 40 and 50 germinate able seeds per m<sup>2</sup>) and fungicide application (without fungicide and with fungicide Signum (boscalid, 267.0 g kg<sup>-1</sup>, pyraclostrobin, 67.0 g kg<sup>-1</sup>) application). Each year 18 variants in 4 replications were sown.

Faba bean sowing dates, depending on each year meteorological conditions, were 26 March 2015, 05 April 2016 and 04 April 2017. Traditional soil tillage was used – mould-board ploughing in the previous autumn and soil cultivation before sowing. Each trial year pesticides were used according to the rules of good agricultural practice. Fungicide Signum was used at GS 61–65 based on trial scheme. Used materials and methods in detail are described in our previous paper (Plūduma-Pauniņa et al., 2018).

During vegetation, main phenological observations were performed. Severity of diseases on leaves and pods (0–9 point scale) was assessed after emerging of first symptoms (not analysed in this paper). Plant height (in cm) was measured after flowering (GS 69). Sample sheet (10 plants) was taken from each plot shortly before harvesting (GS 88). Number of pods and seeds per plant and seeds per pod was detected from sample sheets. Number of productive stems per 1 m<sup>2</sup> was detected after harvesting using 0.5 m<sup>2</sup> frame. Yield (t ha<sup>-1</sup>) was directly harvested from each plot and converted to standard moisture level (14%) and 100% purity.

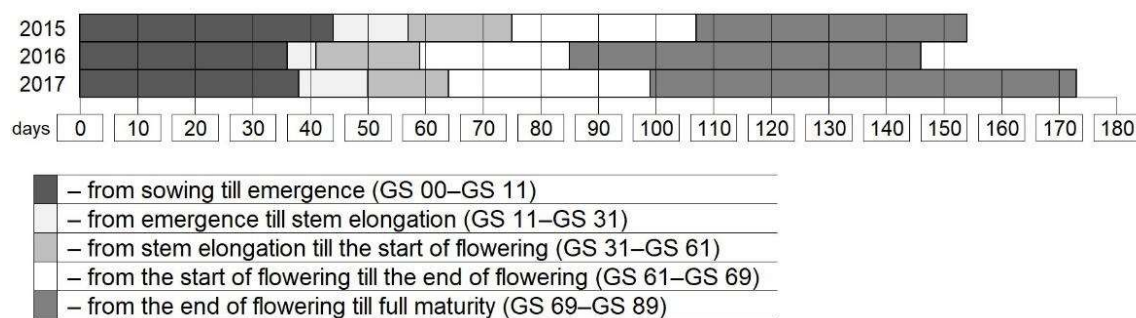
For data mathematical processing three- and four-factor analysis of variance, correlation and regression was used together with Bonferroni test for comparison of factors' means. Variants are considered significantly different when  $p \leq 0.05$ . SPSS 15 and MS Excel softwares were used.

Agrometeorological information was recorded daily by an automatic weather station located near to the experimental field. Meteorological conditions were slightly different each year. In 2015, air temperature was low after sowing, therefore crop germination took longer time, but later temperature and humidity level was suitable for plant growth. During the second part of vegetation season, significant drought and high

air temperatures were observed and cause stress during flowering and pod filling. In 2016, vegetation season was warm and with sufficient moisture level. At the end of the season, overly high moisture level delayed beans' harvest. In last trial year (2017), vegetation season started with a bit cold weather, therefore germination took longer time than in 2016. At the same time, precipitation amount was less, thus faba beans' emergence was faster than in 2015. Further, vegetation period also was mostly cool with a high amount of precipitation, which favoured high yield formation, but delayed harvest for about half a month. For characterisation of faba beans' development, average air temperature, sum of active temperatures (above +5 °C), and sum of precipitation were used (see Results and Discussion section).

## RESULTS AND DISCUSSION

**Phenology.** Plant growth and development is determined by heredity and environmental conditions. Knowing how environmental factors affect crop at each stage of development, we can analyse used management and decide how to improve plant growth, formation of yield and its quality. As meteorological conditions were different in each trial year, we could observe their strong effect on the length of faba bean growth stages (Fig. 1), and adverse effects were observed at some stages of development.



**Figure 1.** Length of faba beans' growth stages in days depending on trial year.

At the end of March 2015, soil temperature and moisture level was suitable for faba bean sowing. After sowing, meteorological conditions changed – air temperature decreased, so soil was not warm enough (average air temperature was 7.5 °C from sowing till emergence), and precipitation level at the same time was high (95.8 mm). For faba bean emergence 44 days were needed. During emergence, sum of active temperatures (262.6 °C; above +5 °C) were calculated. In 2016, the late March and early April was warmer than the long-term average data, so faba beans were sown in first decade of April. Despite suitable moisture level (52.8 mm; long term average 60.4 mm) and quite high air temperature (average 10.5 °C; long term average 8.6 °C) in April, 36 days were needed for faba beans' emergence this year (during this time sum of active temperatures was 313.2 °C). In 2017, conditions were also suitable for faba bean sowing in first decade of April, but after sowing air temperature dropped significantly (average air temperature 5.8 °C) and precipitation level was low (27.4 mm), so faba beans emerged 38 days after sowing (sum of active temperature was 236.0 °C).

Various number of days from field bean sowing time till emergence have been observed in other studies. For example, in trial conducted in Malaysia, in warm climate, (Zabawi & Dennett, 2010) water deficiency prolonged faba bean emergence for 4–7 days, while in 100% water supply plants emerged 10 days after sowing. In another study in Australia, with suitable weather conditions, faba beans emerged 20 days after sowing (McDonald et al., 1994). In Latvia, however, field beans can emerge in 20 days, if they are sown in late April – early May, and suitable weather conditions occur (Holms, 1967).

In 2016, period from emergence to stem elongation was the shortest (5 days), if compared with the same period in 2015 (13 days) or in 2017 (12 days). The cause was insufficient amount of precipitation (in the second and third decade of May precipitation amount was 1.4 mm; long term average precipitation amount in this period is 35.7 mm) and unusually high air temperature during the second half of May (average 18.8 °C; long term average temperature at the same time 12.6 °C).

We can describe the meteorological conditions between emergence and the start of flowering as appropriate for flowering and high yield formation during all trial years. Although the flowering times depending on variety tend to differ, still significant differences in the start of flowering among varieties were not observed during all years (all varieties started to flower in the same day or with one day difference in all the trial years). Slight tendency was observed – field beans sown in plots using lower seeding rate (30 germinate able seeds m<sup>-2</sup>) start to flower first, but this observation was not typical enough.

On average, field beans flower 25–30 days. It is also observed in field and container experiment from Norway, where length of flowering period varied from 2 to 8 weeks. On average for both used varieties in these experiments, it was about 4 weeks – 28 days (Skjelvag, 1981). In 2015, flowering time was 32 days, in 2016 – 26 days, but in 2017 – 35 days in our trials. In 2015, there was high average air temperature during faba bean flowering period (16.4 °C) and reduced precipitation amount at the second and third decade of June (in all flowering period precipitation amount was 47.2 mm; while in June, during the early and full flowering it was only 15.7 mm), but it did not affect faba bean flowering and yield formation as much as drought observed later during pod filling. Studies in Malaysia showed that at 20% moisture availability flowering can be delayed by 35 days (Zabawi & Dennett, 2010). Meanwhile, the end of June and early July characterized with high average air temperature (16.4 °C) and high precipitation level (59.8 mm, most of precipitation was in third decade of June, at the end of flowering) in 2016. It was the reason why faba beans' flowering time was shorter than in other two trial years. However, faba beans can tolerate temporary flooding (Girma & Haile, 2014), thus this factor did not significantly affect their further development. The same tendency was observed in our trial, when after hard rainfall on first decade of July (totally per decade 39 mm, while on 7 July, heavy rainstorm was observed: 22 mm; long term average precipitation amount per this decade is 27.3 mm), half of our field bean trial flooded for about a week. This temporary flooding did not affect faba beans' further development or yield formation. In 2017, average air temperature during flowering period was lower (15.6 °C), but precipitation amount was the highest from all trial years (during the whole flowering period – 84.4 mm; while in June, during the early and full flowering it was half of this amount – 41.0 mm).

Precipitation level during the vegetation period (from sowing to harvest) of faba beans of 2015 was the lowest from all three trial years (233.9 mm; while in 2016 – 317.6 mm and in 2017 – 280.8 mm) and average air temperature was 13.1 °C. The length of faba beans' vegetation season in 2015 was 154 days. In addition, sum of active temperatures was calculated for the period from 1 April till the 31 August to show differences of three trial years. In 2015, sum of active temperatures (above +5 °C) was 2,044 °C. In 2016, vegetation season was 146 days long. This vegetation season characterizes with the highest average air temperature (15.4 °C), and also sum of active temperatures was higher than in previous year (2,244 °C). In its turn, plant growth and development was faster than in other two trial years. Vegetation period of 2017 was 173 days long. Average air temperature during vegetation period was the lowest per trial period – 13.0 °C and sum of active temperatures (1 April – 31 August) was 1,938 °C. Last trial year was cooler than the previous two and this is demonstrated also by average air temperature in period 1 April – 31 August: 13.6 °C in 2015, 14.8 °C in 2016 and 13.0 °C in 2017; in addition, rain was observed regularly, weather was often cloudy, and constant rainfalls were observed at the beginning and middle of August and at the beginning of September in 2017. Such conditions with moderate temperatures and sufficient precipitation level firstly favoured formation of high yield and yield components (see description hereinafter), but secondly delayed faba bean maturity for half a month.

According the results of studies conducted in foreign countries and the experience of field beans' growers from Latvia, the length of vegetation period of faba beans can be different. Two Latvian growers reported 117 and 118 days long faba beans' vegetation period; in both situations, faba beans were sown on 1 May, and they used variety 'Fuego' which can be characterized with early maturity. For comparison, in Australia, the average vegetation period for field beans was 90 days (Loss & Siddique, 1997), in studies in Egypt – 105 days (Badr et al., 2013). In a three-year study in Spain, with one variety and five sowing dates, the vegetation period averaged between 87 days (sowing at the end of April / early May), 99 days (sowing in late March / early April), 124 days (sowing in mid-February), 161 days (sowing in mid-December) and 209 days (sowing in late October / early November) (Villacampa et al., 2009). In a study conducted in Iran, choosing the sowing time of 30 March, which is the closest sowing time to that used in our study, the average vegetation period of the four varieties was 94 days (Ajam Norouzi & Vazin, 2011). Length of vegetation period may differ between varieties. In Ajam Norouzi & Vazin (2011) trial, where four different varieties were used, vegetation period was 95.0<sup>a</sup>; 94.7<sup>a,b</sup>; 93.7<sup>b</sup>; and 92.2<sup>c</sup> days long (different small letters in superscript show significant difference between the length of vegetation periods of used varieties at confidence level  $p = 0.05$ ). In our trial, we did not observe significant differences of vegetation period length between used varieties, the main influencing factor was conditions of the year.

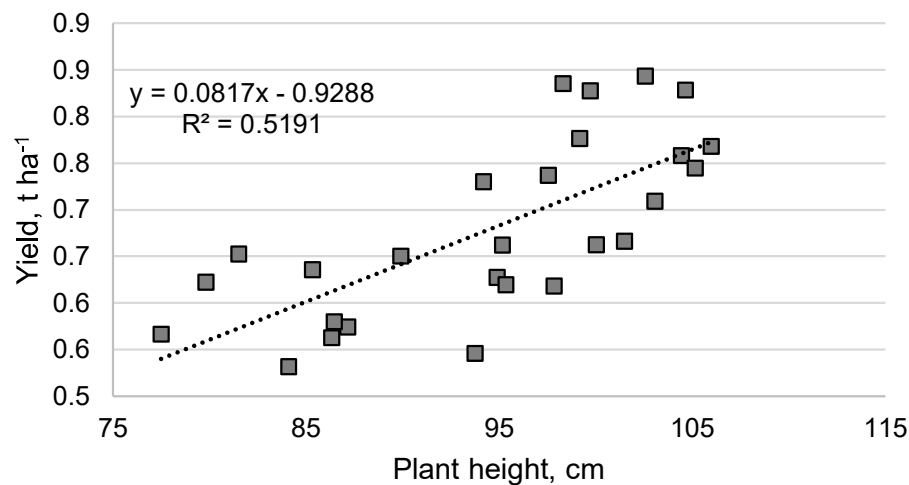
**Plant height.** Plant height was measured right after flowering in all trial years. Plant height differed significantly between years and was affected by variety and fungicide application.

On average per three trial years, variety 'Laura' was characterized with the shortest plants (92.0 cm on average). Average plant height of varieties 'Boxer' (97.7 cm) and 'Isabell' (96.6 cm) was similar ( $p = 0.609$ ), but significantly higher ( $p < 0.001$ ), if compared with that of 'Laura'. In 2015, variety 'Isabell' was highest (91.1 cm), while in

2016, the highest was variety ‘Boxer’ (102.8 cm). In 2017, variety ‘Isabell’ showed the highest plants (103.8 cm), but its plant height did not differ significantly from variety ‘Boxer’ (102.5 cm;  $p = 0.596$ ).

Although the sowing rate did not have a significant effect ( $p = 0.083$ ) on the plant height, we observed that use of higher seeding rate increases plant height in all trial years. This tendency coincides with the data obtained in Pakistan, where 60 plants per  $m^2$  of field beans ensured significantly higher plants, but plant height gradually reduced by decreasing the seeding density to 45, 30 and 15 plants per  $m^2$ , and the shortest plants were observed at the lowest seeding rate (Khalil et al., 2010). Experiments in vegetation containers also showed the same results – use of higher plant density in two-year experiment resulted with higher plants (Al-Suhaibani et al., 2013). The obtained results can be explained by the fact that plant competition begins for light and space at higher plant density (Turk & Tawaha, 2002; Derogar & Mojaddam, 2014).

This could be the reason of observed positive correlation between plant height and yield. If we look at all researched factors together, in 37% of cases, when plant height increased, we obtained higher faba bean yield ( $r = 0.607 > r_{0.01} = 0.364$ ). Meanwhile, analysing only the variants where fungicide was applied, positive correlation tightens and in that case percentage grows up to 52% ( $r = 0.721 > r_{0.01} = 0.487$ ; Fig. 2). Fungicide application increased plant height ( $p = 0.008$ ).



**Figure 2.** Correlation between faba bean plant height and yield if fungicide was applied ( $p = 0.013$ ).

Plant height was affected significantly by conditions in trial year. In 2015, average plant height was 87.1 cm, in 2016, – 97.8 cm, but in last year (2017) – 101.5 cm. It can be explained by different meteorological conditions in each trial year. In 2015, during all vegetation season precipitation amount was the lowest between all trial years (as mentioned before: 2015 – 233.9 mm; 2016 – 317.6 mm; 2017 – 280.8 mm). Still the study of Mwanamwenge et al. (1999) showed that water shortage did not significantly affect plant height, but another study of Zabawi & Dennett (2010) showed a significant effect of water supply on plant height. At 100% of the water supply, field beans reached

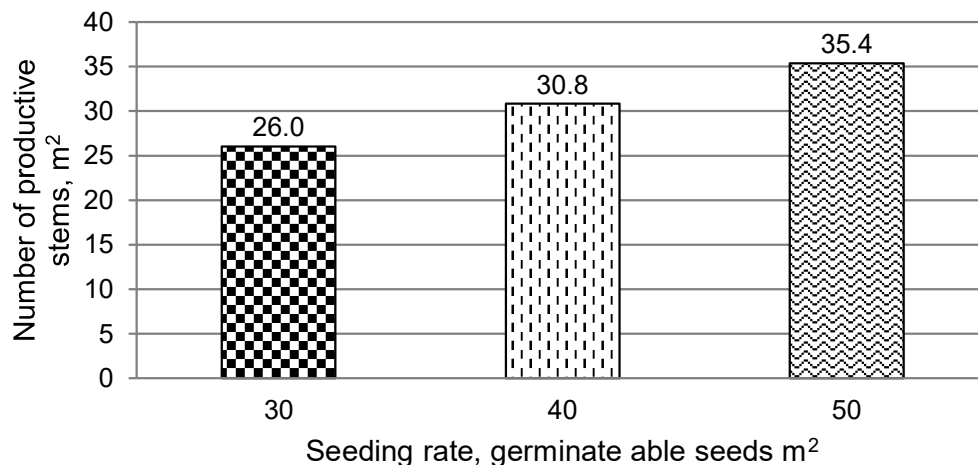
plant height 250 cm, while at 20% of the water supply, they were only 120 cm high. At 40, 60 and 80% of water supply, the plant height varied around 150 cm.

**Productive stems.** The branching capacity of field beans depends on the conditions of the variety and the environment. The branching is associated with the length of the vegetation period – the longer the vegetation period, the higher number of new stems can be formed.

Study results from China showed that winter field beans have a strong branching capacity (up to 25 stems for one plant) when they are sown early; branching is medium (up to 10 stems) when they are sown late. In the spring sown field beans, however, only 2 to 3 stems are formed (Yu & Zhang, 1979). In addition, winter field beans branch mostly until the winter period (46–74% of cases), during winter they branch in 13–33% of cases, whereas after winter plants branch up to 24% of cases (Wu & Jing, 1988).

Although it is believed that branching is not widespread in conditions of Latvia and is seldom observed, plants in this study branched quite a lot. Some individual plants had up to 4 productive stems. Since the field beans in Latvia are sown in spring and the duration of plant growth and development is shorter, if compared with winter field beans, their branching capacity is significantly less than the results of studies performed in other countries show. However, field beans branching possibility slightly increased the number of productive stems per 1 m<sup>2</sup> at harvesting time.

Number of productive stems in this trial was significantly affected only by seeding rate ( $p = 0.01$ ) – higher seeding rate provided more productive stems during harvest ( $r = 0.605 > r_{0.01} = 0.364$ ; Fig. 3) which is logically, because seeding rate is the initial cause of plant density at harvest.



**Figure 3.** Number of faba beans' productive stems at harvest depending on seeding rate.

Despite the fact that significant difference in number of productive stems ( $p = 0.073$ ) was not observed between varieties, higher number was provided by variety 'Laura' (32.0) in all trial years, while variety 'Boxer' provided 31.4 and variety 'Isabell' – 28.9 productive stems per 1 m<sup>2</sup>. This proves information mentioned earlier, that number of productive stems and branching depends also on variety.

In this trial we observed positive correlation between faba bean yield and number of productive stems. It tightens with fungicide application (38% of cases faba beans with higher number of productive stems will provide higher seed yield;  $r = 0.616 > r_{0.01} = 0.487$ ).

Insignificant tendency was observed that in variant, where fungicide was applied, number of productive stems decreased (on average with fungicide application – 30.5 productive stems per 1 m<sup>2</sup>; without fungicide application – 31.0 productive stems per 1 m<sup>2</sup>). Fungicide application also slightly prolonged the length of beans' vegetation period, but this lengthening was not so important to cause simultaneous branching of beans. In 2017, when the longest vegetation period of faba beans was observed (Fig. 1), number of productive stems per 1 m<sup>2</sup> was higher than in previous years due to slightly more intensive branching.

**Pods per plant.** Number of pods per plant can be influenced by the interaction of meteorological conditions and crop growing technology factors (such as seeding rate) (Lopez-Bellido et al., 2005). In our trial, this indicator was significantly ( $p < 0.001$ ) affected by each year's meteorological conditions, seeding rate and fungicide application. Used variety had impact on number of pods per plant each year, but it differed between years; three-year average data did not show significant differences depending on variety (Table 1). On average, the highest number of pods per plant was observed in last trial year (2017). This could be explained with longest vegetation period (length of flowering was 35 days, while in 2015 – 32 days and in 2016 – 26 days; length of period from the end of flowering till full maturity was 74 days in 2017; 47 days in 2015; 61 day in 2016), thus plants had opportunity to produce more flowers that was pollinated and to form more pods per plant.

Although on average variety did not affect number of pods per plant significantly, in each year separately there were significant differences of this indicator between varieties. In 2015 ( $p = 0.045$ ) and 2017 ( $p = 0.001$ ), highest number of pods per plant was obtained by variety 'Laura', while in 2016, by variety 'Isabell' ( $p = 0.006$ ). Variety 'Boxer' did not differ significantly from other two varieties by number of pods per plant in each trial year. Badr et al. (2013) after two-year study showed that significant difference in number of pods per plant (respectively – 18.3 and 11.9 pods per plant) can be observed between varieties.

**Table 1.** Number of pods per plant depending on researched factors

| Factors  | Year                 |                      |                      | Average            |
|--|----------------------|----------------------|----------------------|--------------------|
|  | 2015                 | 2016                 | 2017                 |                    |
| Variety ( $p = 0.05$ )   |                      |                      |                      |                    |
| ‘Laura’  | 12.00 <sup>a</sup>   | 14.15 <sup>b</sup>   | 21.11 <sup>a</sup>   | 15.76 <sup>A</sup> |
| ‘Boxer’  | 10.95 <sup>a,b</sup> | 14.70 <sup>a,b</sup> | 19.25 <sup>a,b</sup> | 14.97 <sup>A</sup> |
| ‘Isabell’  | 10.53 <sup>b</sup>   | 16.01 <sup>a</sup>   | 18.05 <sup>b</sup>   | 14.86 <sup>A</sup> |
| Seeding rate (germinate able seeds m <sup>-2</sup> ) ( $p = 0.001$ ) |                      |                      |                      |                    |
| 30   | 13.52 <sup>a</sup>   | 17.17 <sup>a</sup>   | 20.97 <sup>a</sup>   | 17.22 <sup>A</sup> |
| 40   | 10.90 <sup>b</sup>   | 14.18 <sup>b</sup>   | 20.14 <sup>a</sup>   | 15.08 <sup>B</sup> |
| 50   | 9.06 <sup>c</sup>    | 13.52 <sup>b</sup>   | 17.30 <sup>b</sup>   | 13.29 <sup>C</sup> |
| Fungicide application ( $p = 0.001$ )                                |                      |                      |                      |                    |
| F0   | 11.10 <sup>a</sup>   | 11.96 <sup>b</sup>   | 18.94 <sup>a</sup>   | 14.00 <sup>B</sup> |
| F1   | 11.23 <sup>a</sup>   | 17.95 <sup>a</sup>   | 20.00 <sup>a</sup>   | 16.39 <sup>A</sup> |
| Average  | 11.16 <sup>C</sup>   | 14.95 <sup>B</sup>   | 19.47 <sup>A</sup>   | ×                  |

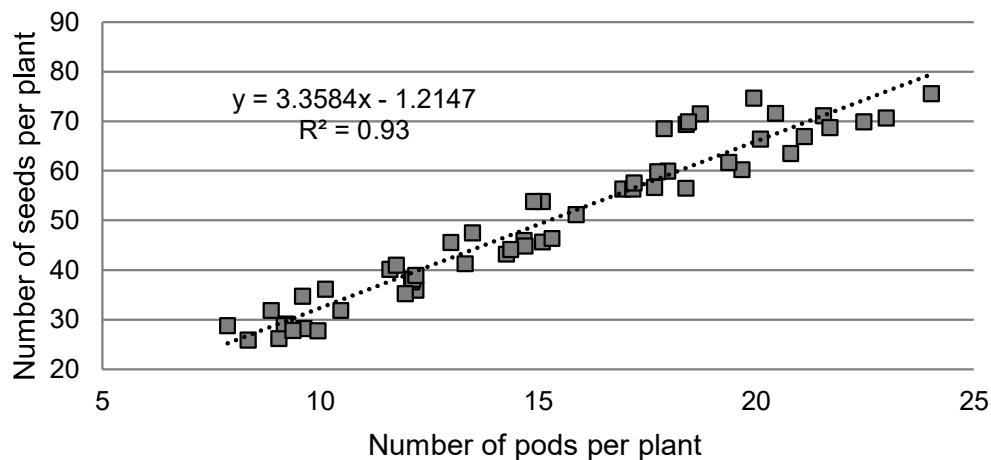
F0 – without fungicide application; F1 – with fungicide application; Significantly different means are labelled with different letters in superscript: <sup>A,B,C</sup> – significant difference for average number of pods per plant of three trial years and means of factors' gradations; <sup>a,b,c</sup> – significant difference in a specific trial year.



Seeding rate effect on number of pods per plant each year was the same – higher seeding rate decreased number of pods per plant. The highest number of pods per plant was obtained using 30 germinate able seeds  $\text{m}^{-2}$  (on average 17.22 pods), while use of 40 and 50 germinate able seeds  $\text{m}^{-2}$  gave respectively 15.08 and 13.29 pods per plant. Coelho & Pinto (1989) and Tuttobene & Vagliasindi (1995) reported similar results – high plant densities prompt greater competition for plant, causing abscission of flowers and decreasing number of pods per plant.

Looking on each trial year separately, fungicide application showed significant ( $p < 0.001$ ) impact on number of pods per plant only in 2016. The cause of such fungicide application efficiency was fairly high spread of diseases (caused by *Alternaria* spp. and *Botrytis* spp.) in 2016 if compared to other trial years. Despite that, each year we could observe a tendency that fungicide application increases number of pods per plant. Positive effect of fungicide application on number of pods per plant was also obtained in various foreign studies (El-Sayed et al., 2011; Emeran et al., 2011; El-Hai, 2015).

Between the number of pods per plant and seed yield positive correlation was observed. Using all trial data, results showed that in 30% of cases plants with higher number of pods per plant will provide higher seed yield ( $r = 0.545 > r_{0.01} = 0.364$ ). Based on the tight positive correlation between the number of pods per plant and number of seeds per plant ( $r = 0.964 > r_{0.01} = 0.364$ ; Fig. 4), also number of seeds per plant positively correlated with yield ( $R^2=28\%$ ;  $r = 0.531 > r_{0.01} = 0.364$ ).



**Figure 4.** Correlation between faba beans' number of pods and seeds per plant ( $p < 0.0001$ ).

Also in two year trial in Australia (Loss & Siddique, 1997), faba bean seed yield correlated with number of pods per plant. In their study, average number of pods per plant was affected by variety and sowing time. For earlier sown plants number of pods per plant was higher (average 19.9 pods per plant) than for later sown (average 10.2 pods per plant) because of the length of vegetation period (Loss & Siddique, 1997).

**Seeds per plant.** Together with number of pods, number of seeds per plant was determined by sample branches. In our trial, number of seeds per plant was significantly ( $p < 0.001$ ) affected by meteorological conditions of trial year and seeding rate (Table 2).

Meteorological conditions during faba beans vegetation period (especially during flowering and pod filling stage) had the most impact on number of seeds per plant. From the end of flowering until full faba bean maturity in 2015 average air temperature was 17.6 °C, precipitation amount – 45.8 mm, while in 2016, average air temperature was 19.3 °C, precipitation amount – 180.4 mm, and in 2017, average air temperature was 15.9 °C, precipitation amount – 135.4 mm. In 2015, number of seeds per plant was the lowest in all three years (36.12 seeds). Pod filling phase (end of July and start of August) characterized with high average air temperature and significant drought, if compared to other trial years. Lack of moisture together with high air temperature affected pod formation and later pod filling with seeds. In 2016, average air temperature during pod filling stage was also high (higher than in 2015), but this stage characterizes with regular and excessive moisture level. Number of seeds per plant was higher than in 2015, but lower than in 2017. Pod filling stage characterized with moderate average air temperature and with sufficient precipitation level during the last trial year. Because of constant rainfalls in the August and early September, vegetation season of field beans prolonged, so pod filling phase also was longer.

Each trial year, with the increase of seeding rate the number of seeds per plant decreased. In 2015, significant differences was observed between variants with different seeding rates ( $p = 0.01$ ). In 2016, only variant with lowest seeding rate (30 germinate able seeds m<sup>-2</sup>) significantly differed ( $p < 0.001$ ) from two others. In 2017, contrariwise only variant where the highest seeding rate (50 germinate able seeds m<sup>-2</sup>) was used differed significantly ( $p = 0.004$ ) from two others (Table 2). Our results coincide with the results obtained by other scientists – that with an increase of seeding rate the productivity of the individual plant decreases (Holms, 1967; Sharaan et al., 2002; Bakry et al., 2011; Barker & Dennett, 2013).

Fungicide application significantly affected number of seeds per plant only in 2016 ( $p < 0.001$ ) because of the spread of diseases, while in 2015 ( $p = 0.711$ ) and 2017 ( $p = 0.068$ ), difference between variants was not significant.

The highest number of seeds per plant was provided by variety ‘Isabell’ in all trial years (53.4 seeds), the lowest – by variety ‘Boxer’ (47.9 seeds), leaving variety ‘Laura’ in the middle (48.3 seeds). In 2015, we did not observe significant difference between all varieties ( $p = 0.289$ ) according this parameter. The same tendency was observed in 2017 ( $p = 0.217$ ). In 2016, variety ‘Isabell’ with 54.5 seeds per plant differed significantly ( $p < 0.001$ ), while between varieties ‘Laura’ (42.4 seeds) and ‘Boxer’ (45.8 seeds) differences was not considerable ( $p = 0.329$ ). Variety effect on number of seeds

**Table 2.** Number of seeds per plant depending on trial year and seeding rate

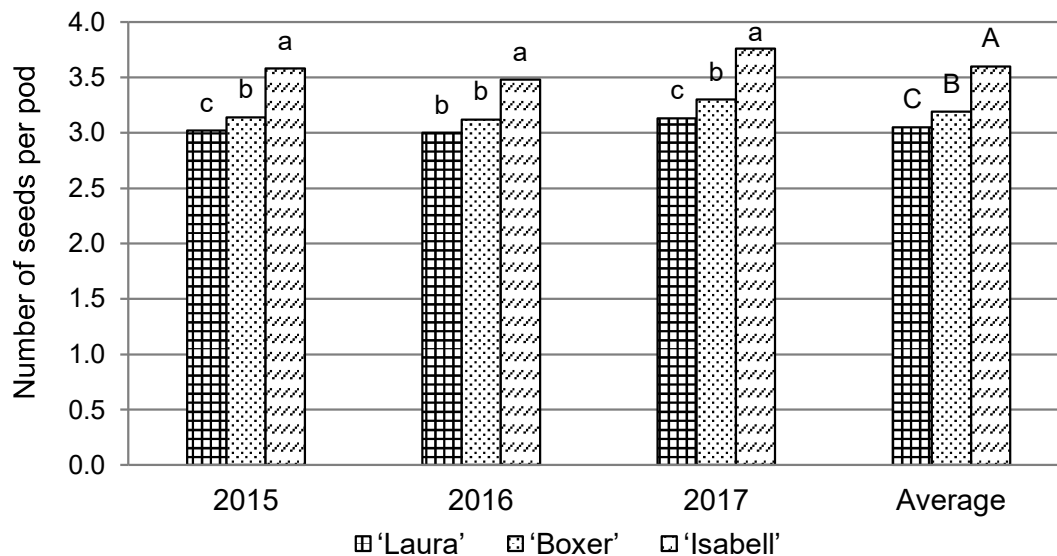
| Factors                      | Year               |                    |                    | Average            |
|------------------------------|--------------------|--------------------|--------------------|--------------------|
|                              | 2015               | 2016               | 2017               |                    |
| Seeding rate ( $p = 0.001$ ) |                    |                    |                    |                    |
| 30                           | 43.73 <sup>a</sup> | 54.97 <sup>a</sup> | 70.70 <sup>a</sup> | 56.47 <sup>A</sup> |
| 40                           | 35.41 <sup>b</sup> | 44.60 <sup>b</sup> | 67.78 <sup>a</sup> | 49.26 <sup>B</sup> |
| 50                           | 29.20 <sup>c</sup> | 43.16 <sup>b</sup> | 58.80 <sup>b</sup> | 43.72 <sup>C</sup> |
| Average                      | 36.12 <sup>C</sup> | 47.58 <sup>B</sup> | 65.76 <sup>A</sup> | ×                  |

Significantly different means are labelled with different letters in superscript: <sup>A,B,C</sup> – significant difference for average number of seeds per plant of three trial years and means of factors’ gradations; <sup>a,b,c</sup> – significant difference in a specific trial year.

per plant can be explained based on seed size. Varieties with smaller seeds produce more seeds per plant, if compared with variety with larger seeds (Holms, 1967).

**Seeds per pod.** Number of seeds per pod is a typical and fairly stable indicator for faba beans. Several foreign studies have shown that on average 3 seeds per pod was noted for *Vicia faba* var. *minor* (Husain et al., 1988; Sharaan et al., 2002; Turk & Tawaha, 2002).

During the trial period, number of seeds per pod was affected significantly by variety ( $p < 0.001$ ), fungicide application ( $p = 0.023$ ) and trial year ( $p < 0.001$ ). The highest ( $p < 0.001$ ) average number of seeds per pod was observed for variety 'Isabell' (on average 3.6) in all years. The last trial year (2017) was characterized by moderate temperatures, enough precipitation, and prolonged vegetation period of beans, and in result most seeds per pod were observed for all varieties (Fig. 5). The fact that the number of seeds per pod is influenced by the variety has also been demonstrated in the above-mentioned Egyptian study (Sharaan et al., 2002).



**Figure 5.** Number of seeds per pod depending on variety and trial year: <sup>A,B,C</sup> – significant difference on average per three trial years; <sup>a,b,c</sup> – significant difference between varieties in specific year.

The average data of three years show significant influence of fungicide application on number of seeds per pod, but in two out of three years this effect was not significant (2015 –  $p = 0.333$ ; 2017 –  $p = 0.487$ ). Only in 2016, fungicide application caused significant ( $p = 0.046$ ) increase in number of seeds per pod (with fungicide application average number of seeds per pod was 3.25, while without fungicide application – 3.15). Similarly as the number of pods and seeds per plant, the number of seeds per pod in this year was influenced significantly by fungicide application based on the spread of the diseases. Despite that, in all trial years the observed tendency was the same – application of fungicide increased average number of seeds per pod.

Meanwhile, seeding rate did not affect this indicator ( $p = 0.830$ ). The tendency in this trial showed, that by increasing seeding rate, number of seeds per pod decreases.

The same tendency was observed in studies in Jordan, based on different sowing rates (50, 75 and 100 germinating seeds per 1 m<sup>2</sup>). Increase of seeding rate causes gradual decrease of the number of seeds per pod. In the case of 50 germinate able seeds per m<sup>2</sup> on average 3.4 seeds per pod were noted, however, when using higher seeding rates, this indicator decreased (respectively – 2.5 and 2.1 seeds per pod) (Turk & Tawaha, 2002).

**Yield and thousand seed weight (TSW).** Faba bean yield was high (on average 5.89–7.38 t ha<sup>-1</sup> depending on the year) and affected significantly ( $p < 0.001$ ) by all researched factors. The highest yield was provided by variety ‘Boxer’ using higher seeding rate (50 germinate able seeds per m<sup>2</sup>) and in variant with fungicide application.

TSW, as a stable indicator related closely to variety and also yield, and was affected by all researched factors. Higher TSW was provided by variety with the highest yield – ‘Boxer’, using fungicide and higher seeding rate.

Detailed faba bean yield and thousand seed weight in this trial was described in our previous paper (Plūduma-Pauniņa et al., 2018), published in journal *Agronomy Research*.

## CONCLUSIONS

Meteorological conditions affected the growth and development of faba beans significantly; drought during flowering and pod filling in 2015 decreased number of pods and seeds per plant and seeds per pod, as well as yield significantly.

Meteorological conditions of the trial year and variety affected plant height significantly. Positive correlation between faba bean plant height and yield was observed.

Number of productive stems was significantly affected only by seeding rate – its value was higher by increasing seeding rate.

Number of pods and seeds per plant was affected by all researched factors. They were significantly higher using lower seeding rate and when fungicide was applied. Positive correlation between both these yield components and yield was observed.

Number of seeds per pod is a typical and relatively stable indicator for the variety. Its value was significantly influenced by the variety and slightly increased when fungicide was applied.

Faba beans’ yield and TSW was significantly affected by all researched factors – variety, seeding rate, fungicide application and year as a factor. Highest yield was provided by variety ‘Boxer’ when higher seeding rates and fungicide was used.

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